1st Asia-Pacific Conference on Plasma Physics, 18-23, 09.2017, Chengdu, China

Study of nonlinear ELM dynamics using both 2-D imaging data and MHD simulation in KSTAR H-mode plasma

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The edge-localized mode (ELM) is an MHD instability driven by both steep pressure gradient and high current density at the pedestal of the high-performance mode (H-mode) plasma of the tokamak. The abrupt heat and particle burst due to quasi-periodic pedestal relaxation, called ELM-crash, can cause irrecoverable damage to first-wall materials. Therefore, it is required to control the ELM-crash to achieve a steady-state long-pulse operation with high beta plasmas. For the reliable ELM-crash control in a wider range of plasma operation condition, an understanding of underlying physics of the ELM dynamics is critical. The measured 2-D ELM dynamics with high temporal and spatial resolution using electron cyclotron emission imaging (ECEI) systems on KSTAR [1-3] have contributed to understanding the ELM physics. Especially, the measured full evolution of the ELMs, from the initial growth phase to crash phase [1], needed a physical interpretation. However, it is limited by poor understanding of the ELM dynamics due to the intrinsic complexity of the ECE signals at the plasma edge and the poor time resolution of the pedestal profile information during the ELM-crash (10^1 – 10^2 μs) phase. All three well-established MHD codes; BOUT++, JOREK and M3D-C1, are introduced for a comparative study with the observations to make sure that the physics interpretation is consistent with the codes. The KSTAR plasma discharge #7328 at $t \sim 4.36$ s is used for nonlinear simulation since the data at this time is extensively studied by a set of BOUT++ linear stability analysis [4]. Here, the edge current reconstruction is improved by introducing the bootstrap current component compared to the previous analysis. Initial conditions of the three codes are matched as much as possible within the operation window of each code, where the solution is numerically stable and easily converged, in a given KSTAR plasma condition. The nonlinear simulation reproduces some part of observations. The mode evolution in BOUT++ results supported the observed mode dynamics such as the transient vanishment of the coherent mode structure and subsequent reappearance with lower-n number just before the onset of ELM-crash. In JOREK, near the onset phase of the ELM-crash, the apparent poloidal rotation of mode decreases in single-mode nonlinear simulation of the $n = 8$ and the magnetic energy of the $n = 1$-3 modes become comparable to that of $n = 8$ (dominant mode at quasi-stable phase) in the multi-harmonic nonlinear simulation [5]. The independent observations and simulations suggest that the low-n mode has high relevancy to the onset of the ELM-crash. To make the hypothesis conclusive, the connection between the low-n mode and ELM-crash will be investigated thoroughly. The M3D-C1 nonlinear simulation in KSTAR geometry is in a preliminary step. The inclusion of the diamagnetic stabilization effect and thermal conductivity, which are included in BOUT++ and JOREK, is in progress for a fair comparison.

This work is supported by NRF of Korea under contract no. NRF-2014M1A7A1A03029865.

References

[1] G. S. Yun, et al, Physics of Plasmas **19** (2012) 056114
[2] J. Lee, et al, Physics Review Letters **117** (2016) 075001
[3] J. E. Lee, et al, Scientific Reports **7** (2017) 45075
[4] M. Kim et al, Nuclear Fusion **54** (2014) 093004
[5] M. Bécoulet et al, submitted to Nuclear Fusion (2017)